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A REVIEW ON RESERVOIR FISHERIES IN CHINA

compiled by

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PREPARATION OF THIS DOCUMENT

This circular has been prepared to fill the need for information on the development of small-scale reservoir fisheries of countries within the region, so as to increase the awareness of the potentials of this practice. Information provided here is based on data acquired from the People's Republic of China.

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ABSTRACT

Inland fisheries of the Indo-Pacific Region has undergone remarkable expansion during the past three decades due to the development of aquaculture. Reservoirs have also been rapidly assuming more and more importance as a source of cheap and accessible animal protein.

Development of the reservoir fisheries of China commenced about three decades ago with the mass construction of water conservancy installations, which include dams for flood control and irrigation.

To raise the fish production in the new reservoirs, the management approach selected was to regularly stock them with valuable fish species which would more fully utilize all the available food. For this purpose, the capture fishery was combined with aquaculture practices, and the "stock-and-take" fishery established.

This circular consists of two parts: (i) a review dealing with fish culture, stocking, capture fisheries, marketing and management of reservoir fisheries in China; and (ii) two case studies. One case study analyses a regular intensive stocking programme which has been carried out for the past two decades, and which has resulted in an average yield of 547 kg per ha annually. This is a typical "stock-and-take" approach now applied in a number of reservoirs in China. The second study shows one of the approaches to solving the shortage of fingerlings for stocking, namely by establishing terraced fingerling ponds on reservoir coves, from which large-size fingerlings are eventually released into the reservoir. This approach, applicable in reservoirs with steep surrounding relief and with a shortage of available land for farm pond construction, results in the supply of fingerlings to areas where no fish seed farms may exist.

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A REVIEW ON THE PRESENT STATUS OF RESERVOIR FISHERIES IN CHINA

1. INTRODUCTION

1.1 Physical Geography of China

China is situated in the eastern part of the Asian Continent, it extends over 5 000 km from east to west and more than 5 500 km from north to south, covering an area of 9 600 000 km², with a coastline of 18 000 km and with some 5 000 islands along its coast.

The major topographical feature of China is that it is high in the west and low in the east. Mountainous, hilly and comparatively rugged plateaus account for two thirds of the total area. China's topography is classified into five major categories: mountainous regions form 33 percent, plateaus 26 percent, basins 19 percent, plains 12 percent, and hilly areas 10 percent.

China has a network of rivers, lakes, streams, reservoirs and ponds, which have a total area of 16.7 million ha. The five major rivers from north to south are the Heilongjiang (3 101 km), Huanghe (Yellow River) (5 464 km), Huai River (1 000 km), Changjiang (Yangtze River) (6 300 km) and the Zhujiang (Pearl River) (2 210 km). The Yangtze River has more than 1 700 lakes distributed along the river, with a total water area of 2.47 million ha, the major ones being the Dongting, Poyan, Taihu and Honze, which have a total water area of 1 219 000 ha.

From the total water area of 16.7 million ha, 5.8 million ha is considered suitable for the production of aquatic products; ponds account for 1.20 million ha, lakes 1.87 million ha, reservoirs 2.0 million ha and small waterways 0.73 million ha. At present, aquaculture and fishing in various forms are being carried out on some 3 million ha of water area (ponds 800 000 ha, lakes 466 000 ha, reservoirs 1 330 000 ha, small waterways 258 000 ha).

1.2 Climate and Precipitation

China is situated in tropical, sub-tropical and temperate zones. The dry season is generally from October to March and the wet season from April to September. Annual precipitation varies greatly over different regions of the country and its distribution over different seasons is also very uneven; floods and drought are still liable to occur. Rainfall decreases from southeast to the northwest; annual average rainfall is 630 mm.

2. RESERVOIRS AND RESERVOIR FISHERIES IN CHINA

Prior to 1949, there were about 20 reservoirs in China. The earliest reservoir built about one thousand years ago was probably the Dong Qian Hu Reservoir in Zhejiang Province on the south-east coast of China. The primary function of this reservoir was irrigation of some 33 000 ha of paddy fields and it is believed to have some fish culture as well. Other notable reservoirs constructed prior to 1949 were the Yuanyang Chi Reservoir in Gansu Province, the Nao De hai Reservoir of Liaoning Province and the Xiao Fengman Reservoir of Jilin Province. Their main functions were irrigation and hydropower. These reservoirs

had some limited capture fisheries, but there was no fisheries management.

China's reservoirs are classified into three categories:

- large reservoirs: storage capacity exceeding 100 million m^3
- medium reservoirs: storage capacity 10-100 million m^3
- small reservoirs: storage capacity 0.1-10 million m^3.

In 1983, China had 86 567 reservoirs of various sizes. Of the reservoirs, medium and small-scale reservoirs constituted the overwhelming majority, with small reservoirs accounting for 96.88 percent of the total, medium reservoirs 2.73 percent, and large reservoirs 0.39 percent. Number, capacity and effective irrigation area of reservoirs in China is provided in Table 1.

2.1 Physico-chemical Conditions

Considerable water level fluctuation is one of the characteristics of reservoirs in China, and this is mainly due to natural conditions and to drawdown for irrigational needs. Water level is usually low during winter and spring, but rises after the monsoon season. This fluctuation places constraints on the production of natural food and spawning of indigenous fish species.

(i) Temperature. Reservoirs situated north of the Yangtze River Basin usually have a short freezing period of nearly one month, whereas reservoirs in the north-eastern part of China have a freezing period exceeding six months.

(ii) Transparency. Reservoirs in China usually have a transparency around 1 m, whereas some may attain 2.5 m.

(iii) The chemical status of a reservoir is determined by the major inflowing river water chemistry and the soil in the immediate region of the reservoir. The pH for China's reservoirs is usually weakly alkaline or neutral. Little variation exists between the surface and the bottom.

The DO content is relatively constant and the water of reservoirs is well oxygenated, with adequate oxygen for the cultivation of fish.

The average organic matter content of China's reservoirs is about 10 mg/l, with a maximum of 45 mg/l and a minimum of 2 mg/l. Nitrate concentrations range between 0.4 mg/l and nil. Phosphate varies between 0.006 mg/l and nil. Iron varies between 0.01 and 0.07 mg/l.

2.2 Food Organisms

(i) Plankton: Diatoms, rotifers and copepods dominate. Quantity of phytoplankton ranges from 200 000 to 300 000/l and zooplankton between 1 500 and 3 300/l.

(ii) Benthos: The dominant forms of the benthos in China's reservoirs are larvae of Chironomus and Branchiura. There are also molluscs, shrimps and crabs in shallows, but, due to the fluctuation in reservoirs, their survival rate is low.

(iii) Vascular plants: Reservoirs in China have very little growth of vascular plants. Depth and fluctuations in reservoirs has greatly inhibited their establishment and survival, which in turn has greatly inhibited the spawning of common carp, crucian carp and other indigenous fish species with the adhesive type of egg.

In general, the natural food of reservoirs is abundant after impoundment, with plankton as the major source. It is because of this situation, that it was emphasized to stock reservoirs mainly with plankton feeders such as the silver carp and big head, and less with black carp and grass carp.

2.3 Composition of Ichthyofauna and its Propagation

The ichthyofauna of China's reservoirs usually consists of two major groups: the original fish species and the stocked species. From the fisheries point of view, stocking is considered the most effective measure in the transformation of ichthyofauna in reservoirs. Some original fish species also adapt themselves well to the new reservoir conditions. For example, the Xenocypris davidi has naturally reproduced in Fu Ziling Reservoir in Anhui Province, and has now attained 11.32 percent of the total yield of this reservoir. But other indigenous fish species such as the common carp and crucian carp in the Chang Shouhu Reservoir in Sichuan Province, due to inappropriate post-impoundment environment spawning conditions, have decreased. With continuous artificial stocking, stocked species have become dominant. In the Chang Shouhu Reservoir, 84.55 percent of the total yield now consists of stocked species. In the Qing Shan Reservoir in Zhejiang Province, after two decades of continuous stocking, stocked species account for 97 percent of the total yield (see the case study in Annex I). Thus, through the implementation of artificial stocking, it is possible to transform the ichthyofauna and increase the yield. As for the non-stocked fish species, their occurrence differs from reservoir to reservoir. Tables 3 and 4 indicate some of such common reservoir fish species and the stocked species.

2.4 Development of China's Reservoir Fisheries

This can be considered in four phases:

(i) The formation phase (1949-1957). A total of 35 large and medium-scale reservoirs, with a total water area of about 250 000 ha, and a few reservoir-associated fish seed farms were constructed. By the end of 1957, approximately 66 000 ha of reservoir water area were utilized for fish culture. Reservoir fish yield for 1957 exceeded 10 000 tons.

During this period, fisheries in reservoirs were characterized as follows:

(a) for small reservoirs, production mode was similar to that of pond fish culture, e.g., with simple bamboo fences or wire netting installed to prevent fish from escaping through sluice gates during the monsoon season. Fishing was carried out on a small scale;

(b) for large flatland reservoirs, the production mode was similar to that of lake fisheries;

(c) for large and medium river type reservoirs constructed in mountainous and hilly regions, post-impoundment surveys and research were carried out on reservoir limnology and biology. Measures were studied of preventing the fish from escaping through the spillways during monsoon season; the feasibility of fish culture and appropriate fishing techniques for the future development of reservoir fisheries were also studied.

From 1950 to 1957, fish culture and stocking programmes were initiated on some reservoirs. The first reservoir to carry out fish culture was the Dong Qianhu Reservoir in Zhejiang Province where a fish farm was established in 1950. Initial stocking was also carried out on some large reservoirs such as the Taipinghu Reservoir in Heilongjiang Province, the Jinpen Yuli Reservoir of Hunan Province and the Guanting Reservoir of Beijing. The fisheries management of large and medium reservoirs was also undergoing a transformation from resource conservation to exploitation and finally to maintaining high sustained yield based largely on artificial stocking.

(ii) The second phase (1958-1965) was the "boom" phase of the construction of reservoirs and development of reservoir fisheries. The majority of the reservoirs in China which exist today were built during this period. Among them are some of the most productive reservoirs in terms of fish, such as the Qing Shan Reservoir of Zhejiang Province, the Sha He Reservoir of Jiangsu Province, the Fu Chaohe Reservoir of Hubei Province and many others. Development of reservoir fisheries in this period was directly related to:

(a) the successful artificial propagation of Chinese carps which has eased the acute shortage of fry and fingerlings required for stocking the reservoirs;

(b) development of a new fishing method, combining various types of fishing nets and the use of sound and visual effects to aggregate and concentrate the fish within a preselected area of the reservoir for seining or in an area where a large stationary net is preset. This method greatly increased the fish yield on reservoirs, as this solved the harvesting of the stocked species, especially the pelagic type of Chinese carps which were the major stocked species in the reservoirs;

(c) culturing of fingerlings in coves within the impoundments.

By 1965, the total reservoir water area under cultivation was 454 600 ha.

(iii) Culturing of Chinese carp (silver and big head) fingerlings in cages without supplementary feeding was the most significant aspect of the third phase (1966-1975). The culturing of fingerlings in cages within a reservoir brought about a new approach to fish culture in reservoirs.

(iv) The fourth development phase of China's reservoir fisheries started in 1977. To enhance reservoir fisheries management and yield, in 1979 reservoir fisheries was put under the supervision of the water conservancy departments. The Ministry of Water Conservancy and

Electric Power (MWCEP) has stipulated that fisheries is to be incorporated into the surveying, designing and construction of future reservoirs. Costs and inputs must include fishery installations and facilities, and special funds allocated annually by the State to improve and complete fishery facilities on reservoirs. In 1984, reservoir fisheries was for the first time incorporated into China's long-term planning of water conservancy projects.

By 1984, 1.3 million ha of reservoir water area had been utilized by aquaculture, and fish yield from this practice yielded 175 000 t (averaging 127 kg/ha). In 1985, the yield was estimated to be 200 000 t. In 1984, a total of 1 300 000 000 fingerlings were stocked in reservoirs. Fish escape prevention facilities for sluice gates and spillways have been provided in over 10 000 reservoirs. Table 2 provides information on China's reservoir fisheries from 1981 to 1984.

Since the take-over of the supervision of reservoir fisheries by the MWCEP, there has been a significant improvement in the self-sufficiency of funds of water conservancy units and fish farms situated on the site of the dam. State-managed reservoirs in some provinces began to have a more favourable balance of revenue with the development of fisheries, whereas in the past they had a slight deficit. Now, the majority of the state-operated reservoirs receive at least 30 percent of their income through fisheries, which has also provided funds for the maintenance of reservoirs, improved the living standards of the staff stationed at the reservoir site, and has also provided employment for their families, such as for example, in the reservoir fisheries development of Hubei Province, situated in central China. This province has at present over 6 200 reservoirs of various sizes. Fish yield for 1984 reached 15 500 t, a 47 percent increase compared to 1980. Revenue from fisheries accounted for 34.5 percent of the total revenue of reservoirs, and over 90 percent of the reservoirs became self-sufficient financially. With the implemetation of the "responsibility and contract system" in agriculture, this is also being practised on some small reservoirs situated in remote rural areas. These are now being allocated to, and managed by households. The carving of a wooden fish for the traditional Chinese New Year dinner to symbolize abundance and surplus of food has now become something of the past in these remote regions, as it could be replaced by real fish. In Shenyang and Fushun (two industrial cities of Liaoling Province in the northeastern part of China), 80 percent of the freshwater fish consumed by the inhabitants and more than half of the total marketable fish in Changde, Hengyang and Yiyang Prefecture in Hunan Province in southern China is supplied by reservoirs.

A characteristic of the development of reservoir fisheries in China is the combining of capture fisheries with aquaculture practices. Many medium and small reservoirs throughout China were constructed by damming intermittent shallow rivers which seldom had any fish. The new reservoirs on such rivers had to be stocked, usually with plankton-feeding species to utilize the rich food base. The "stock and take" mode of fisheries management was based on stocking of the plankton feeding Chinese carps. These species also had a high consumer acceptance and monetary value.

3. FISH CULTURE IN CHINA'S RESERVOIRS

Freshwater aquaculture in China dates back at least two thousand years. Yet reservoir fish culture is a new approach. Prior to 1949, no aquaculture practices were carried out in any of the reservoirs. It was only after the founding of the People's Republic, that China attached the greatest importance to water conservancy measures which were considered the life-line of agriculture. The construction of dams and other water conservancy facilities have contributed to flood control, irrigation, power generation, navigation, industrial and municipal water supply and the development of fisheries.

Flood control and irrigation were the main functions of reservoirs built during the late 1950's, but little or no attention was directed toward fisheries at the initial planning and construction phase of these impoundments. Plans for the development of fish culture in reservoirs were only initiated after the dams had been constructed.

During the first development phase of China's reservoir fisheries, there were about 35 large and medium reservoirs constructed. The State allocated certain funds for the resettlement of the population from the area of the reservoir, and assisted them in the development of agriculture, which included fisheries, for example in the purchase of fish fry to stock the impoundments in order to build up a side-line production for the population situated along the shores of the reservoir. A few State-operated reservoir fish seed farms were also constructed to supply the needed fry for stocking.

The "self-reliance" principles put forward during the 1950's, were also applied to the development of reservoir fisheries. It was not until the early 1960's that reservoir fisheries began to take shape. Fish ponds, fish escape prevention facilities for the sluice gates and spillways of reservoirs, boats and nets were considered the essential requisites for the development of reservoir fisheries. But the dearth of funds slowed down the progress. There were other problems, such as little or no available land within the immediate region of a reservoir to construct ponds. The purchasing of large-size fingerlings from fish seed farms proved to be too costly. To solve the fingerling shortage, ponds were constructed on river beds below the dam, with clay cores to prevent the percolation losses of the fertile pond water. Two methods were developed over the past years for the raising of fingerlings in reservoirs: cove culture, and cage culture.

3.1 Cove Culture

Cove culture of fingerlings was developed in the early 1970's. It utilizes coves within the impoundment by blocking them off from the main water body using small-mesh nets or by earthen dikes. Cove culture of fingerlings in the Chang Shouhu Reservoir in Sichuan Province, utilized the drawdown area in a cove by installing small-mesh blocking nets at two levels within the cove. The total area was 260 ha. The method was to fence off a cove with a slightly larger size (2.4 cm) mesh netting prior to the filling of the impoundment, then to use a smaller mesh (1.2 cm) net in the upper reaches of this fenced off area to form another area for the culturing of fry. A "drape" type small mesh (16 mesh to every 2.5 cm) netting is attached to the upper section of this net to prevent the fry from escaping

through the 1.2 cm mesh netting. Fry of 1.6 to 2.6 cm were stocked during early June in the upper area with the 1.2 cm mesh netting. When fry attained 6 cm in length after 20 days, they were released into the lower netted-off area. As some did not reach the required length when released, another small mesh (1.2 cm) "drape" type of netting was attached to the upper portion of the larger mesh (2.4 cm) size net to prevent their escape. By the middle of August, the average length of fingerlings reached 15 cm, the size suitable for stocking the reservoir. Survival rate of fingerlings was 60 percent without any supplementary feeding or fertilization. By the end of October, a total of 3.5 million fingerlings of silver carp, big head and grass carp of 13 to 19 cm total length were raised through this method.

For cove culture of fingerlings in Sha Hezi reservoir in Jilin Province, 13 terraced ponds with a total area of 31.6 ha were constructed in the upper reaches of a cove. In its 10 years of operation, using supplementary feeding, these produced over 35 million fingerlings (see the case study as Annex II).

In 1983, a national seminar on the rearing of fingerlings in reservoirs was held in the county where Sha Hezi reservoir was situated. The seminar established that the practice of Sha Hezi reservoir in raising fingerlings had considerably contributed to overcoming the shortage of fingerling ponds, and recommended this practice for other reservoirs with similar morphometry.

3.2 Cage Culture

The successful use of floating net cages without supplementary feeding to culture silver carp and big head fingerlings was first carried out by the Hydrobiology Research Institute of the Chinese Academy of Science in 1973. Among the reasons why cage culture gained such recognition and popularity in reservoirs throughout China are: no land is required; the better utilization of water space; no supplementary feeding and fertilizers are needed; the low cost; and the high productivity and easy management. Various studies and experiments have been carried out over the past years by fisheries research institutes in the field of cage culture techniques, species density, rearing ratio, growth, construction and location of cages in reservoirs, wintering of fingerlings in cages, etc. Special motorized boats were designed and constructed for use in the operation of cage culture of fingerlings (hauling of cage for inspection and cleaning of netting).

Cage frames are usually made of wooden poles, bamboo poles or plastic piping. Cages float on frames, supplemented with plastic floats or old metal drums. Sinkers are usually made of iron, stone or pottery. Anchors, prefabricated cement slabs or stones are used for the positioning of cages. The recommended mesh size for the raising of fingerlings is 0.7 to 1.5 cm, and the size of a cage ranges from 20 to 40 m^2.

The stocking density is usually 200 to 500 fry/m^2, depending on the availability of natural feed within the impoundment and duration of the growth period.

To promote the cage culture of fingerlings in reservoirs, a technical meeting, sponsored by the Water Conservancy Project Management Bureau of the MWCEP, was held in 1981 at the Da Huofang Reservoir in Liaoling Province. The meeting adopted guidelines for the floating cage culture of silver carp and big head fingerlings; and guidelines for the wintering of fingerlings in cages in the northern regions of China.

Studies and experience acquired over the past years from the cage culture of fingerlings in reservoirs suggest that it is more feasible in eutrophic reservoirs. In oligotrophic reservoirs or those with heavy siltation, cage culture gives poor results. For reservoirs low in nutrients and natural food, a lower stocking density was advised, generally not exceeding 150 fish fry per m^2.

Reservoir fisheries in China is based on an assumption that the highest yield is achieved by the stocking of species which do not propagate in impoundments, with species that do propagagte contributing only a small portion to the total yield. Thus, reservoir fisheries strategy in China relies on regular stocking, which also demands a regular provision of large-size fingerlings. A stocking density of 1 500 large-size fingerlings per ha for the total of 2 million ha of reservoir area, requires 3 000 million fingerlings annually. Currently, there is a 1 700 million shortfall. Although earthen ponds shall continue to function as the major production environment, especially for culturing of fry, other approaches need to be developed to satisfy the demand for fingerlings. One approach is to culture fry in ponds, small fingerlings in cages supplemented by ponds, and large sized fingerlings in cages or coves according to the actual environmental conditions of an impoundment. More in-depth studies and research are still needed.

4. STOCKING IN RESERVOIRS

Stocking of fry or undersized fingerlings is a common phenomenon in China when reservoirs are first constructed. The availability of fingerlings is determined by their availability from pond culture and by funds available for their purchase. For example, reservoirs in Jiangsu Province are mostly stocked with small fingerlings of 6.6 and 9.9 cm[1]/ only. Some reservoirs are even stocked with fry of 2.5 to 3.0 cm in length which of course gives very poor returns. Due to the small stocking size and the presence of predators, the return rate for the Sha He Reservoir in Jiangsu Province has been only 4.4 percent over the past two decades. In contrast, the Qing Shan Reservoir in the province of Zhejiang was stocked with fingerlings of 16.5 cm which attained a weight of up to 1 kg within a year. The return rate of fish for this reservoir was 50 percent. Studies and experiments carried out on optimal stocking sizes of fingerlings for reservoirs have proved that the minimum size of Chinese carps should be at least 13 cm as they have a much higher survival and return rate.

1/ A conversion from the Chinese measurement. Fry and fingerlings are measured in "cun", 1 cun = 3.3 cm. All measurements for fry or fingerlings refer to total length.

Conclusions derived from research work carried out by the Freshwater Fisheries Research Institute of Zhejiang Province are that a fingerling exceeding 13 cm in total length stocked in a reservoir in a temperate region is equal to the stocking of three 9.9 to 13 cm fingerlings or to 12 fingerlings less than 9.9 cm.

Stocking density is another aspect in the development of aquaculture in reservoir fisheries. Some reservoirs stock excessive quantity of fingerlings which cannot be supported by the naturally available food. It has been believed that the high stocking rate would increase the survival rate. Such an approach shows a poor understanding of stocking principles. For example, the Da Xi Reservoir in Jiangsu Province was stocked with 2 330 000 fingerlings (average 3 495 fingerlings per hectare) after the eradication of predators and unwanted species due to the drying-out of the reservoir. Due to this high stocking density and shortage of food organisms after refilling, large quantities of big head and silver carp died during the spring of the second year, and more than 80 percent of these two stocked species harvested two years after stocking reached only 150 to 200 g.

Studies have shown that the optical stocking densities for reservoirs situated in the provinces of Jiangsu, Zhejiang and Shandong should be 1 500 to 2 250/ha of 13 cm fingerlings. For small or more fertile impoundments, the density could be slightly increased.

It has also been noted that big head produces much better results than silver carp in oligotrophic reservoirs, and vice versa in eutrophic reservoirs.

Post-impoundment surveys have shown that other species of fish of economic value such as the common carp, crucian carp, Plagiognathus microlepis and Megalobrama amblyocephala are not stocked. The reason is that these species spawn naturally in the impoundments. It was reported from Fu Zheling Reservoir in Anhui Province that in the late 1960's when the reservoir dried out it was possible to harvest all the fish. This enabled the total biomass to be determined of the non-stocked species which was formed to be 60 kg per ha. It was evident that total reliance on the natural spawning of these species contributes little to the total yield. In contrast with that, the stocking of crucian carp in Wuyi Reservoir in the province of Heilongjiang resulted in the yield of 112-150 kg/ha for the past decade. Setting up of artificial spawning nests, using small bundles of grass within the spawning area to collect eggs of natural spawning fish species of economic value is also carried out in this reservoir during the spawning season when heavy drawdown occurs.

In southern China, in reservoirs stocked with Cirrhinus molitorella highest yield was 225 kg/ha.

Studies and experience derived from stocking practices have shown that the stocking of fish of various feeding habits leads to a better utilization of reservoir niches, and gives a higher yield.

5. INTEGRATED FISH FARMING IN SMALL RESERVOIRS

This practice originated from pond fish culture and is now also being practised in small reservoirs. For example, the fisheries managers of the Jin Penzhai Reservoir (Hubei Province), a small reservoir of 30 ha, have, for the past four years, utilized the run-offs and bean starch dregs from a vermicelli factory to feed pigs. Manure of pigs was then used to fertilize the water. This, supplemented with grass, increased the fish yield from 750 kg to 1 350 kg per ha. The Zhongxin Reservoir (Yunan Province) with an area of 53.5 ha is culturing grass carp. The reservoir fishery management utilizes the drawdown area to plant barnyard grass (Echinochloa crusgalli) as feed for grass carp, and this produces a yield of 1 500 kg of grass carp per hectare. Grass carp and common carp account for 50 percent of the total fish yield.

Aquaculture in reservoirs is basically an extension of the traditional polyculture system successfully established in pond fish culture. The practice carried out in the past of stocking silver carp and big head in the majority of the reservoirs in China as the major stocked species is applicable and feasible, as established by various surveys. However, attention should also be given to other cultivable fish species of economical value to occupy the vacant niches within impoundments.

6. CAPTURE FISHERIES IN RESERVOIRS

6.1 Fishing Gear

The artificial propagation of Chinese carps has provided the basis for reservoir-associated aquaculture for production of fingerlings. The next problem was that of harvesting. Reservoirs usually have an uneven bottom with numerous obstacles, such as rocks and submersed trees, as only rarely bottom grading or clearing is done prior to impoundment. Fishing gear and methods that were successful in fishing in large natural flat-bottom bodies of water and which were introduced into the reservoirs were therefore not always effective. Fishing in the reservoirs at the initial stages was very much in a passive state, giving low yields. As a consequence this led to some doubt on the feasibility of the development of reservoir fisheries.

During the initial stage of the development of reservoir capture fisheries, seine net, various types of gill nets and hooks used in marine and freshwater lake fisheries were applied. Although the trammel net produced the best results, its catch rate was limited by the resources within the impoundment.

Preconditioning of bottoms of impoundments in China is usually carried out in medium and small-scale reservoirs, as less capital investment and manpower inputs are required. Preconditioning includes grading and clearing of submerged obstacles such as tree stumps, walls of dismantled houses, tombstones, stone walls, boulders, etc. It is now considered that more thorough preconditioning should be carried out in small artificial impoundments where conditions meet future intensive culture. For medium and large impoundments, selective grading and clearing is favoured. For coves that are to be utilized for future fingerling culture, thorough preconditioning is required.

The dominant types of fishing gear presently used in capture fisheries on reservoirs in China are the trammel net, large set nets, seine net operated from powered boats, beach seine net, gill net, hooks and the trawl net.

The majority of the fishing boats in reservoirs are of wooden structure and non-motorized. Types and shape vary considerably, but length and width is generally betwen 5 and 7 m and 1.8 and 2.5 m respectively, using oars or sculls. Some of these boats are converted into motorized boats by adding an outboard engine. Specially built motorized fishing boats for reservoir fisheries are usually larger in size (10-12 m in length), with a horsepower varying between 12 and 40 HP.

In March 1984, a seminar on the standardization of motorized fishing boats for reservoir fisheries, sponsored by the MWCEP, was held in Dalian, Liaolin Province. Considering the water area and future needs in reservoir capture fisheries, it concluded that motorized fishing boats should be multipurpose, and a horsepower between 3.5 and 40 HP was recommended.

6.2 Fishing Methods

Fishing on reservoirs during initial stages was mostly in the passive state, giving low yields. Gears used mainly consisted of gill nets of various mesh sizes, trammel nets and hooks. Based on behaviour studies of silver carp and big head and experience acquired in reservoir capture fisheries, a fishing method using various types of nets was first developed by the Xinanjiang Reservoir of Zhejiang Province in 1964. This intensive fishing method catches a large percentage of the stocked species within a short period. It consists of the application of various types of nets, such as the trammel net, retreat prevention net, seine net and/or a large set net, and of the use of sound and visual effects (utilizing white coloured small and narrow wooden boards tied to a rope and towed under water by a motorized boat), to aggregate the fish and to block their retreat with retreat prevention nets. This concentrates the fish within a preselected area where seining is possible, or to where a large stationary net is preset. This fishing method is now widely used, and largely due to its application the fish production in reservoirs in China has greatly increased. Further, improvements in the aggregating of fish were achieved by utilizing the pulse electrical current. Compared to the original method this resulted in a saving of 50 to 70 percent of costs, and the time spent in the aggregating of fish was also reduced two to four fold.

Although this fishing method is common, improvement is still needed. Problems that have come to light are: the high investment and low utilization of nets and gear which are used only once or twice a year; poor catch rate of demersal Chinese carps; frequent use of this method decreases fish catch. There is also need for a more efficient method for fish removal from set nets.

Seasonal fishing or selective fishing for certain species is also carried out, such as fishing with gill nets and trammel nets for demersal Chinese carps and for predators.

Seining from a motorized boat is also practised. For example, the seine net operation conducted on the Fu Zheling Reservoir in Anhui Province from a 60 HP boat has in the past two decades produced 2 370 t of fish, averaging 103 t annually.

Apart from the types of fishing practices carried out in reservoirs as mentioned above, trawl fishing on a more limited scale is conducted in reservoirs with water areas exceeding 1 000 ha. A recent development in this field is the experimental pair trawling with a four-panel large-mesh net developed by the Dalian Fisheries College, using polyethylene as netting material and 40-HP boats. Although production trials have shown good results, it is limited to large reservoirs where conditions meet trawling requirements and appropriate fish species are present.

Much attention has been given to the control of predators in reservoirs stocked with Chinese carps. Among predators, those that are most abundant and most harmful in China's reservoirs are the Elopichthys bambusa, Erythroculter ilishaeformis and the E. mongolicus. Fishing for predators on reservoirs with stocked Chinese carps in China is carried out throughout the year, especially during their spawning. Biological and ecological studies, as well as experimental fishing for Elopichthys bambusa in the Fu Qiaohe Reservoir in Hubei Province, showed that the yield of this predator declined from 63 percent by weight to 0.75 percent of the total yield. At the same time, annual fish yield of stocked species increased from 48 750 kg to over 250 000 kg. Other reservoirs that in the past were infested with the above mentioned predators have also carried out similar measures with good results.

6.3 Fish Escape Prevention Facilities

Fish escape prevention facilities are considered an essential fishery requisite for reservoirs in China, and they are applied according to the type of the reservoir. In mini-reservoirs, bamboo baskets are used. For small and medium reservoirs with shallow overflow of low velocity and little floating debris, bamboo fences or polyethylene netting is used. The most common fish escape prevention facility for sluice gates and spillways in medium and large reservoirs is polyethylene netting which is set where flow does not exceed 0.5 m/s.

As debris may pile against fish escape prevention nets making them inoperational or destroying them, some small reservoirs in Fujian Province have installed with good results the pulse type electric fence to prevent fish from escaping.

7. MARKETING CHANNELS FOR FISH CATCH

The two marketing channels for fish harvested in reservoirs in China are: (i) purchasing stations of the China National Fisheries Corporation (CNFC), and (ii) free market. Purchasing stations are set up by the nationwide supply and marketing companies of the CNFC throughout the country where fish production or fish landings are more concentrated, as is especially the case in marine fisheries. For inland fisheries, purchasing stations are established at certain points along the shores of lakes and large reservoirs with more or less evenly distributed fishing effort throughout the year.

However, as the majority of reservoirs are usually situated in regions not easily accessible, and intensive fishing is only carried out once or twice annually, the purchasing and transporting of the bulk catch to large cities and surrounding regions is usually pre-arranged between the reservoir management units and the nearest purchasing station, with the latter providing the transportation facilities. Although fish is consumed all the year round in China, the peak seasons are autumn and winter.

Fish that are harvested throughout the year in small quantities or quantities exceeding the quota, are usually sold fresh on nearby free markets for local consumption. Prices of fish sold on the free market are negotiable.

As marine fish in the past were, and at present continue to be, the bulk of China's fishery production, various types of processing and preservation facilities were set up along the coasts and in areas with high freshwater fish production. In view of the widely scattered reservoirs, some basic preservation and storage facilities are urgently needed for marketing the produce in distant markets and making it available throughout the year.

8. MANAGEMENT OF RESERVOIR FISHERIES

Water conservancy facilities in China are supervised and managed by water conservancy departments. This is especially the case for large-scale reservoirs, whereas medium and small reservoirs although supervised by water conservancy departments, are usually managed by townships and production brigades. Fisheries considerations are now incorporated in the surveying, designing and construction of new reservoirs. Costs and inputs must include fishery installations and facilities, and special funds are allocated annually by the State to improve and complete fishery facilities presently in operation on reservoirs. Since 1979, a series of meetings, seminars and symposia have been held throughout the country to enhance the development of reservoir fisheries. Those of significance are: the meeting on the development and future work on reservoir fisheries held in 1981; the national meeting on the integrated development of water conservancy projects held in 1982; the symposium on facilities for the prevention of fish escaping through sluice gates and spillways and fishing techniques on reservoirs held in 1982, all sponsored by the Ministry of Water Conservancy and Electric Power (MWCEP); and the symposium on scientific and technical long-term planning for reservoir fisheries, sponsored by the Hydrobiology Research Institute of the Academy of Science.

These and many other meetings, seminars and symposia held over the past years have greatly promoted the development of reservoir fisheries. Fish yield in 1981 attained 119 000 t, an increase of 30 percent since 1978. There has been an increase in the income from fisheries at the majority of the State-operated reservoirs. Thirty percent or more of the total income of the reservoir management unit is now being derived from fisheries. This has provided funds for the maintenance of dams, improved living standards of staff stationed at the reservoir and provided employment for their families. In the Hubei Province, with 6 200 reservoirs, fish yield for 1984 reached 15 500 t, a 47.6 percent increase compared to 1980. Income from fisheries accounted for 34.5 percent of the total revenue from

reservoirs and over 90 percent of the reservoir management units became self-sufficient financially through the development of fisheries.

There are three basic forms of fisheries management in China: (i) state managed; (ii) jointly managed by reservoir management units and the related township(s) or brigades, and (iii) managed by households or individuals through the contract system.

(i) State-managed. Large-scale reservoir fisheries are state-managed. All aspects of fisheries, i.e. from the raising of fingerlings to stocking and fishing are carried out by operation groups which consist of workers attached to the reservoir management unit. On some large reservoirs, contracts are signed between the operation groups (usually fingerling raising, fishing and supply services), and the reservoir management unit for the fulfilment of various operations, besides the wages. Seventy to eighty percent of the profit is distributed among the group members according to their work input. The reservoir management unit takes the remaining 20 to 30 percent.

Management of the water areas of large reservoirs is carried out by a reservoir management committee. Members of the committee consist of the reservoir management unit, the relevant township(s) and production brigades. If water areas border other counties or provinces, those that are directly related to the reservoir are involved. The total water area is divided into sections, the township or brigade of each county being responsible for the management of that area of the reservoir assigned to it. Remuneration, derived from fisheries income, is allocated to the person(s) responsible for the managed water area. For example, in the development of fisheries of the state-managed He Di Reservoir (6 733 ha) in Guangdong Province, southern China, the reservoir management unit now has 152 persons operating and managing two hatcheries, 32 ha of fingerling ponds, coves and cages, and some 50 fishing boats. This reservoir has also issued fishing licenses (based on an annual fingerling fee) to some 590 households to carry out fishing, thereby improving the livelihood of some 2 500 inhabitants in production brigades living along the shores of the reservoir.

(ii) Jointly-managed. This is practised on medium and small reservoirs, with only a limited staff stationed at the dam site. The principle for this development is that fisheries in the reservoirs are jointly developed and managed by reservoir management units, and township or production brigades, and that profit and loss from joint investments are the responsibility of both parties. There are various forms of this type of fisheries management: some reservoirs are jointly operated from the rearing of fingerlings, management of water area to the harvesting; others assign the development of reservoir fisheries to the production brigades through the contract system. The production brigade is entitled to retain and market the fish harvested in excess of the contract. An example is the fisheries in Hou Longhe Reservoir (166 ha) in Rong Cheng County, Shandong Province, which has been jointly developed and managed between the reservior management unit and 15 production brigades of 4 townships since 1971, through a joint management committee and fishery operation unit consisting of 20 persons from the 15 brigades. Allocation of the net income from this practice is 70:30 between the production brigades and the reservoir management unit.

(iii) Household or individually-managed. This system is now being practised in small or mini-reservoirs, which have greatly promoted the development of fisheries in underutilized or unutilized small reservoirs situated in remote rural regions. Contractors, either household(s) or individual(s) sign a contract with the reservoir management unit or the production brigade for the development of fisheries in a small impoundment, which includes stocking, management and harvesting. Conditions are that a certain percentage of income and fish are provided to the reservoir management unit or the production brigade. Provisions for the use of water during the irrigation/-dry season are provided. Methods of fishing and fish size limits are also stipulated in these contracts. An outstanding example in this respect is the Si Hui County in Guangdong Province, where 96 percent of the county's small and mini-reservoirs are allocated to households or individuals for the development and management of fisheries, which is carried out through a contract system. This increased the county's annual fish yield from 92 500 kg in 1983 to 187 500 kg in 1985.

The Regulation on the Propagation and Conservation of Aquatic Resources, first issued in 1957, was repromulgated by the State Council in 1979. In January 1986, the first Fisheries Law of the People's Republic of China was passed by the Fourteenth Session of the Standing Committee of the Sixth National People's Congress, and came into force on 1 July 1986. This Fisheries Law consists of six sections, 35 articles: (i) general rules (8 articles); (ii) aquaculture (5 articles): (iii) fishing (5 articles); (iv) propagation and conservation of fisheries resources (9 articles); (v) legal responsibility (6 articles); (vi) supplementary articles (2 articles). Two articles in the legal responsibility are directly related to the Criminal Law. Detailed rules and regulations for the implementation of the Fisheries Law are now being drawn up.

The above Regulation and Fisheries Law are also implemented in reservoir fisheries.

There is a closed fishing season (usually one to two months) during the spawning season on reservoirs. The actual period varies from north to south.

As reservoir fisheries have become an important element in the integrated development of water conservancy projects, training and research in reservoir fisheries have also been stepped up considerably and a number of organizations are involved, such as fisheries research institutes, fishery colleges, and the recently established China's first Reservoir Fisheries Research Institute of the Chinese Academy of Science. The Faculty of Fisheries of the Agriculture College of Huazhong now provides college graduates in reservoir fisheries, and also offers training courses on reservoir fisheries for technical personnel stationed at various reservoirs. A Project Engineering Management Training Centre, supervised by the MWCEP provides short-term training courses on reservoir management, including fisheries, for management personnel.

Since the MWCEP became in charge of reservoir fisheries, training courses have been offered in the fields of aquaculture, fishing gear and methods, stock assessment, stocking programmes, resource conservation and reservoir fisheries management. Such courses are run by provincial water conservancy bureaus with the assistance of fisheries

research institutes, such as the Hydrobiology Research Institute of the Chinese Academy of Science and fisheries colleges, and secondary fisheries technical schools.

The periodical "Reservoir Fisheries", which first appeared in 1981, is a quarterly publication on the development of reservoir fisheries. It is now published bi-monthly and is called "Water Conservancy Fisheries". It has a broad approach to the integrated development of reservoir fisheries and to fisheries development in the context of water conservancy projects.

9. SUMMARY

This review summarizes the development of China's reservoir fisheries over the past three decades and discusses its achievements. The major approach to an increase in freshwater reservoir fish yield is the combination of capture fisheries and aquaculture. Introduction of new aquaculture technologies, improved fishing methods and management, as well as intensified research and training, have greatly contributed to the goal of increasing the fish supply to improve the nutritional level of the population of China.

Reservoir fisheries has scope for expansion as one-third of the total reservoir area (660 000 ha) is still unexploited. Management measures can increase fish yield in reservoirs with existing fisheries, where especially increases in technology inputs and improved stocking practices can be applied. Extension work and training in the development and management of reservoir fisheries is urgently needed for fisheries personnel stationed at reservoirs. There is also a need for synthesis and evaluation of data accumulated from post-impoundment studies in the fields of limnology and fisheries biology of reservoirs. Such evaluation should then be used for more precise planning of reservoir fisheries development.

Table 1

Capacity and Irrigated Area of Reservoirs in China (1983)*

Item	Total	Reservoirs (size in million m^3)		
		Large (> 100)	Medium (10 - 100)	Small (0.1 - 10)
Number of reservoirs	86 567	335	2 367	83 865
Capacity (100 million m3)	4 208.2	3 006.5	640.4	561.3
Effective irrigation area (in million ha)	15.671	6.081	4.251	5.339

* Statistical Yearbook of China, 1984. English edition

Note: Figures in this table are preliminary

Table 2

Reservoir Fisheries in China from 1981 to 1984

Year	Fingerling rearing ponds* (ha)	Fishing boats			Fishing gear (n)	Yield (tons)
		Total	Motorized	% of motorized		
1981	8 610	20 100	1 880	10.7	6 440 000	119 000
1982	9 318	20 505	2 120	10.3	7 030 000	130 000
1983	9 936	21 300	2 920	13.6	NA	149 000
1984	10 866	24 000	NA	NA	12 500 000	175 000

* Includes fenced off coves with nets or earthen embankments

NA = not available

Table 3

Some Indigenous Fish Species Found in China's Reservoirs

Cyprinus carpio	Misgurnus anguillicaudatus
Carassius auratus	Ophicephalus argus
Xenocypris davidi	Siniperca chuatsi
Xenocypris argentea	Distoechodon tumirostris
Hemiculter leucisculus	Abbottina rivularis
Elopichthys bambusa	Plaiognathops microlepis
Opsariichthys uncirostris bidens	Acanthobrama simoni
Erythroculter ilishaeformis	Rhodeus sinensis
Erythroculter mongolicus	Barbodes (Spiniobarbus) sinensis
Ochetobibus elongatus	Varicorhinus simus
Pseudorasbora parva	Hemibarbus labeo
Pseudobagrus fulvidraco	Monopterus albus
Silurus asotus	Squaliobarbus curriculus

Table 4

Fish Species Presently Stocked in China's Reservoirs

Hypopthalmichthys molitrix (silver carp)	Aristichthys nobilis (big head)
Ctenopharyngodon idellus (grass carp)	Mylopharyngodon piceus (black carp)
Cyprinus carpio (common carp)	Carassius auratus (golden carp)
Megalobrama amblycephala (Wuchang bream)	Parabramis pekinensis (white amur bream)
Cirrhinus molitorella (mud carp)	Plagiognathops microlepis

Annex I

CASE STUDY: Development of Fisheries in the Qing Shan Reservoir since its Impoundment in 1960

ABSTRACT

This case study discusses a successful development of fisheries in a small reservoir in South East China. The Qing Shan Reservoir, with a surface area of 800 ha, and situated 40 km west of Hangzhou, Zhejiang Province, belongs to Chinese reservoirs with the highest fish yield. In the two decades of managed fisheries, it has produced 6 429 t of fish, averaging 547 kg per ha per year. The major factor responsible for this success is the regular intensive stocking. This "stock-and-take" approach is commonly applied in China's reservoirs, but the resulting fish yield still varies considerably.

1. INTRODUCTION

The Qing Shan Reservoir is situated 40 km west of Hangzhou, provincial capital of Zhejiang Province on the southeast coast of China. It was completed in 1960 by damming the upper reaches of the small Dong Shao river draining the East Tianmu Mountains. The primary functions of the reservoir are flood control, irrigation and hydroelectricity. The Qing Shan Reservoir not only is one of the earliest reservoirs to develop reservoir fisheries after impoundment, but also one of the most productive reservoirs in China in terms of fish. In its 22 years of fisheries development (1962 to 1983), it has produced 6 429 t of fish, averaging 547.96 kg per ha per year. In 1984 it produced 410 t with an average of 768.8 kg per ha. This was achieved by a team of two technicians, 22 workers and 18 casual labourers.

2. RESERVOIR CHARACTERISTICS

2.1 Morphometry, Physico-chemical and Biological Characteristics

The reservoir is situated on the northern fringe of the subtropical zone. Major precipitation periods are May to June and September, the latter month being the typhoon season. The average annual rainfall is 1 300 to 1 400 mm. The average air temperature is 15.9°C, and the average annual water temperature (measured 0.5 m below surface) is 18.0°C.

The catchment area of the reservoir is only 603 km². Full storage capacity is 215 x 10^6 m³. When full, the reservoir covers 800 ha, of which the area suitable for fishery purposes is 533.3 ha.

Maximum depth is 14 m; mean depth is 7 to 8 m. The bottom of the impoundment consists of flooded crop land, with some gravel and a thick layer of silt.

The catchment area is mainly cultivated land and forest. As the densely populated Lin An County with many small villages is located upstream from the impoundment, the catchment supplies ample organic matter and nutrients to the reservoir which, as a result of this, is eutrophic. The soil of the catchment area consists of acid loess and brown forest soil. Forests consist of sub-tropical evergreens, the main species being pine and China fir.

As flood control is one of the primary functions of this reservoir, the water level is usually kept high during the summer and autumn after the monsoon season, and the water level is lowered during the winter, beginning to rise again during the coming spring. The maximum annual drawdown from 1974 to 1983 ranged between 9.95 and 9.01 m.

From surveys conducted between October 1979 and September 1980, transparency measured with a secchi-disc ranged from 0.8 to 1.5 m. Annual average conductivity of water is 131 micromhos. For average values of the major physico-chemical characteristics of reservoir water, based on samples taken from the surface, intermediate and bottom water layers in the upper, mid and lower reaches of the reservoir during 1980, see Table 1.

The following information on fish-food organisms is based on surveys from 1973 to 1975.

Phytoplankton: Diatoms formed 37.2 percent, Chlorophyta 32.3 percent, Dinophyta 17 percent, Xanthophyta 5.1 percent, Euglenophyta 4.6 percent, Chrysophyta 3.1 percent and Cyanophyta 0.7 percent. Such a composition of phytoplankton is considered favourable for the growth of the silver carp.

Zooplankton: The dominant species were protozoans (86.3 percent), followed by rotifers, cladocerans and copepods.

Benthos: The major types were Limnodrilus, Plumatellidae, Viviparus quadratus and freshwater clams.

Phytoplankton is inhibited by high turbidity during the monsoon season, and there are losses of plankton due to spillway overflow. The water level is usually stable during autumn, when the density of plankton is highest. During winter, the water level is low and stable, surface temperature remains around 7°C, with Dinophyta and Euglenophyta abundant. The highest biomass of benthos is found in spring, and the lowest during summer and autumn.

2.2 Fish Species Composition

Fish of the reservoir belong to six orders: Cypriniformes, Anguilliformes, Beloniformes, Perciformes, Ophiocephaliformes and Tetrodontiformes. There are 12 families: Cyprinidae, Cobitidae, Siluridae, Serranidae, Anabantidae, Eleotridae, Anguillidae, Hemirhamphidae, Ophiocephalidae, Serranidae, Bagridae and Catostomidae. The Cyprinidae are represented by eight sub-families: Cyprininae, Leuciscinae, Xemocyprininae, Hypophthalmichthyinae, Gobioninae, Abramidinae, Acheilognathinae and Barbinae, with a total of 42 species.

Predators are Erythroculter ilishaeformis, E. mongolicus and Siniperca chuatsi. Their size and stocks are small and therefore do not endanger the stocked species. Measures to control the increase in predators are regularly applied.

None of the original fish species present in the impoundment could support a fishery on a commercial scale without intensive stocking. The major stocked species are big head (Aristichthys nobilis) and silver carp (Hypophthalmichthys molitrix). Other species stocked are grass carp (Ctenopharyngodon idella), common carp (Cyprinus carpio), black carp (Mylopharyngodon piceus) and the bream (Megalobrama amblyocephala).

3. FISHERY

3.1 Stocking of Fingerlings and their Proportion in the Final Yield

Since the establishment of the reservoir, the fingerling stocking programme has been changed several times.

During the first period (1961 to 1966), the major species stocked was the silver carp. The stocking density was 1 200 to 1 350 per ha, and the fingerlings stocked were rather small (about 9.9 cm[1]/). The average yield per ha was 510 kg.

During the second period (1967 to 1979), the major species stocked was the big head carp. The stocking density was 1 500 to 1 800 per ha, and the average size of stocked fingerlings increased to 13.2 cm. The average yield per ha was 660 kg per ha.

In the third period (1980 to 1983), 80 percent of the fingerlings of big head and silver carp stocked were 13.2 cm in size, and the remaining 20 percent of these stocked species were of a weight of 14 to 16 fish per kg. Stocking density was 1 650 to 1 800 per ha. The average yield per ha was 682.5 kg. Table 2 provides the stocking rates and annual yield of the Qing Shan Reservoir from 1961 to 1983. The relationship between stocking rates and annual yield is shown in Table 2.

During the 22 years, a total of 24 537 000 fingerlings were stocked. The big head constituted 41.6 percent and the silver carp 32.2 percent of the total, whereas other species accounted for only 26.1 percent. The results of this stocking mode were reflected in the yield with 95.6 percent of the total yield consisting of big head and silver carp and other species accounting for only 4.4 percent. The return rate of these two stocked species is between 49 and 51 percent. For every 1 kg of fingerlings stocked, 14.4 kg of marketable fish were produced.

The yield and average body weight of big head and silver carp for the period 1973 to 1976 are given in Table 3. It should

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1/ A conversion from the Chinese measurement "cun". 1 cun = 3.3 cm. All lengths of fingerlings are referred to as total length.

be noted that fish marketed from the Qing Shan Reservoir belonged mainly to the second year class.

The stocking programme was 800 000 to 1 000 000 fingerlings annually (equivalent to between 1 500 and 1 876 per ha). Stocking of larger fingerlings has led to a much higher survival rate and yield, with fingerlings of 13.2 cm increasing the returns by 50 percent. Fingerlings of this minimum size attained 0.6 kg in weight within one year, which is 20 percent more in weight than when stocking fingerlings of less than 13.2 cm.

Another change was the timing of the stocking. Prior to 1968, fingerlings were stocked in March and April, but after 1968 they were stocked from the end of December to the beginning of January. The reasons for this were that: (i) the smallest loss when transporting fingerlings from fish seed farms occurs during winter, when fingerlings are less active; (ii) during winter the water temperature is higher in the reservoir than in the fish ponds and feed is relatively abundant; (iii) transplanting fingerlings during winter from a small pond to a large water body enables them to adapt themselves well to their new environment; and (iv) the feeding activity of reservoir predators is low during winter. Thus, the stocked fingerlings, having adapted themselves throughout the winter period to their new environment, are more active when the water temperature increases during the spring, and the chances of them being caught by predators are greatly reduced.

3.2 Intensive Culture of Grass Carp in Tailwater

The Qing Shan Reservoir has also carried out intensive culture of grass carp on an experimental scale by utilizing the tailwater from the turbines. The tailwater is first stored in a storage tank and then transferred to the elliptical cement ponds, each having an area of 24.56 m^2. The total experimental area was 326.7 m^2. The weight of the grass carp stocked was 24 fish to every kg, with a stocking density of 150 fish per square metre. With 7 months rearing time, the survival rate was 42 percent and the yield attained was 8 657 kg, averaging 26.5 kg/m^2. Grass was used as supplemental feed.

3.3 Fish Escape Prevention Facilities

As the development of fish culture in China's reservoirs is mainly in the mode of stock-and-take, preventing fish from escaping through sluice gates and spillways is of great importance, especially during the monsoon season. In 1963, two years after the start of fisheries development in the reservoir, the Freshwater Fisheries Research Institute of Zhejiang Province, assisting the reservoir's development, designed fish escape prevention nets for the sluice gate and spillway, using anchors to station the nets. The nets were made of PVC with the total length of the net for the spillway being 280 m, the maximum height 20 m, the mesh size 4 cm and the hanging ratio 0.55/0.66. Since impoundment, the maximum flow within the spillway recorded has been 395 m^3/s and the reported velocity of flow, where the fish escape prevention net had been set (180 m from the entrance of the spillway), did not exceed 0.5 m/s, a flow speed that

enabled fish that came into contact with the net to swim back into the reservoir. Since the installation of the fish escape net, no loss of fish has been reported during the flood seasons.

3.4 Harvesting

In order to enhance the survival rate and growth of stocked species, the competition and other pressures from predators and miscellaneous fishes are minimized by intensive fishing of these species during their spawning season and when schooling during mid-winter.

Large-scale short-term intensive fishing for stocked species is conducted twice a year, usually during autumn and winter. The fishing method applied usually consists of using a combination of various types of fishing nets such as the retreat prevention nets, trammel nets, seine nets and a large set net. Also used are sound and visual effects (usually a motor boat towing white coloured small and narrow wooden boards tied to a rope under water or with a motor boat generating electric pulses) to aggregate the fish in the reservoir, and to block their retreat with retreat prevention nets. This concentrates the fish within a preselected area of the reservoir where seining is possible or in an area where a large stationary net is pre-set. This fishing method is quite popular in reservoirs in China, especially with stocked pelagic Chinese carps, which are the main stocked species throughout China. It was this fishing method that greatly promoted fisheries development in China's reservoirs, whereas prior to its introduction, fishing for stocked species in reservoirs had always been passive, giving low yields.

Some selective fishing for larger fish of the stocked species is also done in order to reduce the density of fish and, hence, the competition for food when there is a heavy drawdown during dry seasons due to irrigation demands.

During the 22 years (1961 to 1983), the Qing Shan Reservoir produced 6 429 t of table fish with a mean yield of 279.5 t per year. The highest yield was 490 t, which is equivalent to 919 kg per ha per year. The highest single fish haul recorded was 350 t. Fish yield for the past 5 years has been relatively stable, with an annual yield of around 360 t. The present cost of rearing 1 kg of fish is 0.44 yuan, which includes the purchasing of fingerlings, wages, feed, depreciation of nets, and taxes. The reservoir is now a supplier of fresh fish to the provincial capital Hangzhou, Lin An County, and the villages in the vicinity of the reservoir.

Beneficial results from the development of reservoir fisheries are quite significant. In 1961-1981, the revenue from fisheries was 2 986 600 yuan (US $807 189)[1/], which is 54.3 percent of the total revenue of the reservoir. Net profits from fisheries were 1 610 000 yuan (US $435 135). The rest of the revenue came from irrigation charges. With the income from

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1/ US $1 = 3.70 yuan (August 1986).

fisheries, the Qing Shan Reservoir became self-sufficient in management funds from 1965. Funds from fisheries have been used for the maintenance of the dam, the construction of irrigation facilities and fish ponds.

After 1978, the new economic directives of the government delegated more economic responsibility to the reservoir management. From 1979 to 1981 both fish production and income increased. Compared to 1979, fish production in 1980 increased by 4.7 percent, and profits increased by 16.6 percent. In 1981, fish production increased by a further 5.4 percent and profits by 18.9 percent. With the increase in production and profits, staff wages also increased, and public welfare improved with the building of staff dormitories, the setting up of a kindergarten, bath house, reading room and television rooms.

4. DISCUSSION

The Qing Shan Reservoir is one of the most productive Chinese reservoirs in terms of fish yield. The management strategy adopted in the development of fisheries in this reservoir is stock-and-take. Such a strategy is common in Chinese reservoirs, but has varying results. The most significant factor in the development of fisheries in the Qing Shan Reservoir is the continuity of stocking over the past 22 years. This has resulted in high fish yields but, nevertheless, some problems still exist. These include:

(i) Severe shortage of fingerling rearing facilities. For the past 22 years, the Qing Shan Reservoir has been stocked with an average of 1 115 300 fingerlings per year, yet the reservoir has only 2.66 ha of fingerling rearing ponds. The majority of the fingerlings needed for stocking are purchased from fish seed farms in Hangzhou, Yuhang, and Deqing Counties which are situated 40 to 60 km from the reservoir. This, no doubt, significantly increases the cost and causes some mortality during transportation.

(ii) Fishing of undersized marketable fish. Fortunately, such fish form only 6 to 10 percent of the total catch which is due to the use of some small mesh size nets. There is scope to further reduce the small size fish portion of the total catch.

(iii) Low stocking rate of demersal species of fish. For the past two decades, great importance has been given to stocking of silver carp and big head, while stocking of demersal species of fish has been much neglected. For example, 357 500 demersal fish were stocked in the reservoir from 1980 to 1983 (grass carp: 53 000; bream: 137 000; others: 167 500), accounting for only 8 percent of the total stocked fish. Apart from the low stocking rate, there was also a problem with catching the fish. The low returns of 3 percent of the total yield for the period 1980 to 1983, largely reflect the inefficiency of the gear.

(iv) Low proliferation of indigenous fish species. Indigenous fish species of economic value that spawn naturally within the reservoir are the common carp, crucian carp and the Xenocypris davidi. Drawdown during the spawning season due to agriculture needs (which sometimes reduces the total area to about 200 ha), has caused the adhesive type of eggs of these fish species to be stranded on the shores of the reservoir, resulting in a high loss of eggs.

(v) Inadequate enforcement of fish stock protection measures against illegal fishing due to the shortage of management personnel.

5. RECOMMENDATIONS

Further improvement in the Qing Shan Reservoir fish yield could be achieved by implementing the following measures:

(i) Comprehensive measures should be taken to solve the acute shortage of fingerling rearing facilities. As there is a shortage of land in the vicinity of the Qing Shan Reservoir for establishing a hatchery, which is also a common situation encountered at a number of other reservoirs in China, other approaches are needed for the reservoir to become self-sufficient in fingerlings. An improvement could be achieved by raising the fry in ponds for a shorter period than at present, then transfering them to net cages and/or coves within or near the reservoir to reach the size suitable for their release into the reservoir. This would safeguard the release of an adequate number of large size fingerlings.

Development of cage culture for the intensive rearing of some marketable herbivorous and omnivorous species such as the grass carp, common carp and bream with supplementary feeding could also be considered.

(ii) Harvesting and marketing of undersized fish is uneconomic as it increases production costs. Readjustment of the year class composition in catch by simultaneously harvesting the 2 and 3 year class groups and selecting the mesh size of nets accordingly would be an appropriate approach.

(iii) More efficient utilization of the benthos biomass will be achieved by increasing the stocks of demersal fish species through an increased rate of stocking. The growth of terrestrial vegetation on the exposed drawdown area provides an abundance of food for the grass carp, bream (Megalobrama amblycephala), common carp, crucian carp and the Xenocypris davidi when the land is reflooded during the monsoon season. Benthic fauna such as Limnodrilus and chironomid larvae are also plentiful in the impoundment. By increasing the stocking density of the above mentioned species of Chinese carps, it should be possible to increase the

percentage of bottom dwelling fish from the present 3 percent to 10 percent of the yield.

(iv) Measures should be undertaken to improve the natural spawning of the originally riverine fish species. During the spawning season which coincides with the considerable drawdown, it is recommended to set up artificial spawning nests, such as bundles of fresh grass, within the spawning area to collect eggs of naturally spawning fish. These eggs should then be placed into ponds for hatching, rearing and eventual release of fingerlings back into the reservoir. This approach should result in an increase of the hatching and survival rates of such fish.

(v) The protection of reservoir fish stocks should be enhanced by the application and enforcement of fisheries management measures in agreement with the new fisheries law.

Table 1

Physico-chemical Characteristics of the Qing Shan Reservoir

1.	pH	7.6 - 8.7
2.	Dissolved oxygen (mg/l)	5.5 - 10.6
3.	Total alkalinity (mg/l)	1.25 - 2.47
4.	Calcium (mg/l)	21.6 - 41.7
5.	Nitrate (mg/l)	0.2
6.	Nitrite (mg/l)	0.012
7.	Total nitrogen (mg/l)	0.31 - 1.81
8.	Phosphate (mg/l)	0.2 - 1.2
9.	Chloride (mg/l)	4.1 - 8.7
10.	Sulphate (mg/l)	7.1 - 63.4
11.	Fe+++ (mg/l)	0.01 - 0.5

Table 2

Stocking Rates and Annual Yield of the Qing Shan Reservoir (1961 to 1983)

Year	Fingerlings Stocked (thousands)				Annual Yield (t)		
	B.H.*	S.C.*	Others	Total	B.H. and S.C.	Others	Total
1961	33	288	4719	5040	NA	NA	8.2
1962	38	188	NA	226	56.5	22.0	78.5
1963	99	225	83	407	26.5	18.7	45.2
1964	247	416	NA	663	NA	NA	149.2
1965	278	360	13	651	245.5	5.4	250.9
1966	359	348	68	775	252.1	21.6	273.7
1967	428	299	11	738	288.7	23.1	321.8
1968	386	303	11	700	192.0	20.6	212.6
1969	230	215	10	455	329.1	14.6	343.7
1970	346	246	46	638	360.4	6.2	366.6
1971	414	270	75	759	NA	NA	NA
1972	494	288	75	857	473.5	14.4	487.9
1973	1148	375	86	1609	418.9	18.1	437.0
1974	627	610	112	1349	281.4	14.6	296.0
1975	557	246	87	890	342.9	8.3	351.2
1976	588	304	102	994	320.4	9.3	329.7
1977	716	288	192	1196	329.1	11.3	340.4
1978	468	431	134	1033	NA	NA	336.0
1979	530	540	228	1298	330.5	10.2	340.7
1980	585	510	123	1218	348.4	11.7	360.1
1981	515	309	93	917	365.0	11.3	376.3
1982	586	408	109	1103	395.9	11.4	407.3
1983	531	463	27	1021	306.2	9.8	316.0
Total	10 203	7 930	6 404	24 537	5 673.0	262.6	6 429.0

* B.H. = Big head (Aristichthys nobilis)

S.C. = Silver carp (Hypophthalmichthys molitrix)

NA Not available

Table 3

Yield and Average Body Weight of Big Head (*Aristichthys nobilis*) and Silver Carp (*Hypophthalmichthys molitrix*)

Yield	Quantity (%)		Weight (%)		Weight (g)	
	Class		Class		Class	
	2 year (1+)	3 year (2+)	2 year (1+)	3 year (2+)	2 year (1+)	3 year (2+)
Maximum	92.2	22.2	78.4	43.3	875	3 000
Minimum	78.8	7.8	56.7	21.6	275	650
Average	85.2	14.8	69.3	30.7	490	1 350

Annex II

CASE STUDY: The Use of Terraced Ponds in Reservoir Coves for Fingerling Production

ABSTRACT

The Sha Hezi Reservoir is situated in a hilly region in the temperate climate of northeastern China. The main problem with this reservoir in the development of reservoir fisheries was to overcome the shortage of available land in its vicinity which prevented the construction of fingerling ponds. This was solved by damming the upper reaches of the coves within the impoundment area and converting them into 13 earthen banked terraced fish ponds for the rearing of fingerlings. These fingerlings were then used to stock the reservoir and to supply fingerlings to the neighbouring townships within the county which had no fish seed farms. This approach could improve the supply of fish seed in remote regions. In the past ten years, using supplementary feeding, the Sha Hezi Reservoir has produced 35 310 000 fingerlings. From 1972 to 1980, the reservoir also produced 520 000 kg of table fish, averaging 411 kg per ha.

1. INTRODUCTION

The province of Jilin where the Sha Hezi Reservoir is situated is in the northeastern part of China. This province has at present 16 150 reservoirs of which 97 are of medium size, 1 224 of small size and 14 829 of mini size[1]/. The total water area is around 200 000 ha, 133 000 ha of which are suitable for fish culture. The State-managed cultivable reservoir area accounts for 68 percent (90 386 ha), and fish yield from this area accounts for 60.7 percent of the total aquaculture yield in the province.

Reservoirs situated in the eastern and mid-eastern areas of the province are of the mountain river type. In the middle of the province, they are of the hilly type while those in the flatlands in the west of the province are of the lake type.

2. GENERAL CHARACTERISTICS OF THE SHA HEZI RESERVOIR

The Sha Hezi Reservoir is situated 9.0 km east of the Shu Lan County township of Jilin Province in the northeastern part of China (lat. 44°N, 127°E). The reservoir, completed in 1968, has a catchment area of 102.8 km²; it has a maximum capacity of 10 300 000 m³, and 140 ha are considered suitable for fish

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1/ China classifies its reservoirs as:

large size: > 1 000 ha
medium size: 100 - 1 000 ha
small size: 10 - 100 ha
mini size: < 10 ha

culture. The primary functions of the reservoir are irrigation and flood control; the irrigated areas cover 2 100 ha.

The special feature of the reservoir fisheries is the utilization of gullies above impoundment coves to rear fingerlings for stocking in the reservoir and to supply fingerlings to the neighbouring townships within the county.

Being situated in a hilly region, numerous gullies and ridges surround the catchment area of the Sha Hezi Reservoir. The hilly region is densely covered with trees and bush, and with a thick layer of humus, thus providing the reservoir with an ample quantity of organic matter through run-off.

The climate is continental, of the cool temperate type, with an annual mean temperature of 3.5°C. There is a frost-free period of 130 days from early May to late September. Annual sunshine averages 1 389 hours and the average annual precipitation is 668 mm. The freezing period is from the end of November to mid-April with a thickness of ice of 70 to 90 cm.

3. CULTURE OF FINGERLINGS IN TERRACED PONDS

The gullies above coves have a dense covering of plants and chernozem soil rich in humus. Parts of the gullies have grassy marshland soil. Some of these gullies were selected for the construction of ponds. For the area of the fish ponds, their water volume, mean and maximum depths, and the length of their shoreline, see Table 1.

Prior to 1971, the Sha Hezi Reservoir had only 1.53 ha of fingerling rearing ponds and the fingerlings reared fell far short of the demand. To overcome the contradiction between the need of ponds for the culturing of fingerlings and the shortage of agricultural land, a survey was conducted on the feasibility of utilizing the depressions between the ridges above the reservoir's maximum water level and the possibility of adapting such gullies to more or less permanent pond-type storage by constructing earthen dams. Such ponds would then serve for fingerling culture. The survey noted that the soil was suitable and the land slightly sloping with easy access and drainage.

By 1981, 13 terraced fingerling ponds were constructed between four ridges at different levels. Their total area was 37 ha. The total water volume of these ponds above the coves was 935 000 m^3, with one-third consisting of water from the runoff and the other two-thirds being pumped from the reservoir. The physico-chemical characteristics of the Sha Hezi Reservoir and of three terraced ponds are shown in Table 2. Apart from the 13 terraced fingerling ponds, there are also four two-stage pump stations, 1.7 km of power line, 3.5 km of roads between the ponds, and hatchery facilities for producing 30 million hatchlings, the latter not yet fully operational. Over the past 10 years, the construction resulted in 290 000 m^3 of earthwork, which is equivalent to the earthwork done for the main dam of the reservoir.

The total investment for the above construction was 680 000 yuan (US $183 783), from which 480 000 yuan (US $129 729) were funds earned from fisheries. The average cost for every hectare of fingerling pond area constructed was 18 150 yuan (US $4 905) which is similar to the price for constructing a fishpond in flatlands. The cost for producing every 10 000 fingerlings was 193 yuan and the cost per kg of fingerlings was 1.60 yuan. From 1972 to 1982, the total accumulated income from fisheries was 1 928 000 yuan (US $521 081) with income from fingerlings being 1 195 000 yuan (US $322 972), which is 80 percent of the reservoir's total revenue.

The present case study is based on the records of terraced pond rearing of fingerlings above the coves in 1984, which attained an average per ha yield of 4 484 kg in 13 ponds (total water area of 30.8 ha).

3.1 Species Stocked and their Growth

To prevent an outbreak of disease in ponds, they are dried in rotation during the winter after 2 years of uninterrupted use. The freezing of dried ponds exterminates a portion of pathogenic bacteria. Ponds are disinfected by applying lime (1 500 kg/ha), 7 to 8 days prior to the stocking of fry in the spring. If ponds are not stocked within 15 days, bleaching powder is used (187 kg/ha). Under such treatment, no outbreak of disease was reported.

The Chinese carps stocked in the terraced ponds in June 1984 were fry of silver carp, big head and grass carp, purchased from a fish farm in Suzhou, Jiangsu Province (a distance of more than 2 000 km away). Common carp were hatched locally on 25 May. By 18 June, silver carp had reached a length of 2.27 cm, big head 2.59 cm, grass carp 2.29 cm and common carp 2.27 cm. The stocking ratio for small fry was 55 percent silver carp, 10 percent big head, 15 percent grass carp and 20 percent common carp. After 90 days, the average length of silver carp was 15.5 cm, big head 14.5 cm, grass carp 10.5 cm and common carp 9.9 cm.

3.2 Rearing Procedures

The fingerling culture adopted and implemented by this reservoir is basically the same as that of pond fish culture, with emphasis on the physico-chemical conditions of the water in the terraced ponds.

(i) The fish stock density is gradually reduced with the filling of water. Ponds are filled in stages, and this results in the "dilution" of the fish stock. For example, pond no. 7 was stocked with 2 680 000 big head fry on 28 May (the area then was 0.53 ha, the average depth 1.5 m and the water volume at about 8 000 m^3), this being equivalent to a stocking density of 5 025 000 per ha. On 8 June, the average depth was increased to 2 m, the total water volume to 14 400 m^3 and the area to 0.8 ha. This reduced the density to 3 345 000 per ha. The pond was filled again on 15 June, resulting in an increase in water area to

1.06 ha, an average depth of 2.25 m, a total water volume of 24 400 m^3, and a decline in fish density to 2 512 500 per ha. By this time, the initial density was reduced by 50 percent. This density is higher or equivalent to fry cultured in flatland ponds.

(ii) Filling and draining of water in terraced ponds. To increase the growth space for fry and to reduce the range of dissolved oxygen concentration (DO) and temperature, filling was initiated in June and the first half of July. By the end of July, full water level was reached and water stratification was established. Additional filling of the ponds did not improve the oxygen content near the bottom, where feed was lost as fry could not utilize it. DO at the surface was below 4 mg/l, and nearly zero at the bottom. The pH at the surface was 7.0 to 7.2, whereas near the bottom it was 6.0 to 6.5. The transparency was less than 25 cm. The DO, pH and transparency improved when a portion of the oxygen deficient water was drained out (about one-quarter to one-third of the total volume) and fresh water added.

(iii) Feeding pattern and quantity. During the rearing of fry, soyabean milk was sprayed over the ponds for 3 to 4 days, the quantity (dry weight) being 0.5 kg per day for every 10 000 fry. This practice was continued throughout June. By July, the fish were lured by feed to pond embankments and fed twice a day. Initially, they were fed soyabean milk, then the diet was gradually changed to two-thirds bean dregs and one-third wheat bran, the quantity increasing from 3 to 6 kg per day for every 10 000 fry during August. Thereafter, the fry were fed once every two days and the quantity reduced to 3 kg per day for every 10 000 fry until the fingerlings were transferred to fewer ponds for wintering.

(iv) Application of chemical fertilizers. Prior to the rearing, the terraced ponds are disinfected with lime and/or bleach powder, grasses on the pond bottom and in the drawdown area are removed and the pond is filled with water. When transparency exceeds 50 cm at 6 a.m. or the difference in transparency between the morning and afternoon readings is lower than 5 cm, the pond is filled or drained. A chemical fertilizer (urea) is added according to the fertility of the water at a rate of 22 to 52 kg of urea per ha.

DO, pH and transparency were recorded at 6 a.m. and 4 p.m. daily, to determine the quantity of feed and whether to fill or drain the pond, so as to maintain the most favourable ecological conditions possible.

(v) Yield. After 110 to 115 days of rearing, the total yield of fingerlings was 138 123 kg (4 198 493 fingerlings), averaging 4 484.25 kg (9 088 fingerlings) per ha. Fingerlings less than 9.9 cm in length accounted

for 9.1 percent, from 9.0 to 12.87 cm: 19.9 percent, from 13.2 to 14.52 cm: 12.7 percent, and from 14.85 to 17.16 cm: 58.3 percent.

The total amount of feed fed during this period was 159 150 kg (15 000 kg of soyabeans, 94 150 kg of bean dregs and 50 000 kg of wheat bran).

The total expenditure during this rearing procedure was 207 123 yuan (feed 25.2 percent; management 8.5 percent; energy, wages, depreciation, funds and sundry fees 66.3 percent). Production costs per kg of fingerlings were 1.52 yuan. Fingerlings were sold locally at 3.28 yuan per kg. The total output value was 453 046 yuan and production profits per kg of fingerlings were 1.76 yuan.

4. DISCUSSION

In the development of reservoir fisheries in China, the shortage of fingerling rearing facilities due to the lack of available land in the vicinity of a reservoir is a common phenomenon. In the past, this considerably inhibited the development of reservoir fisheries in China. The purchasing of larger size fingerlings from fish seed farms greatly increased costs, which often resulted in irregular stocking programmes due to a shortage of funds. Various methods have been introduced in the past to overcome this problem, such as: (i) constructing ponds below the impoundment on sandy river beds with a core of clay; (ii) establishing cove culture or cage culture of fingerlings; and (iii) a combination of these fingerling culturing methods.

The utilization of the upper reaches of coves within an impoundment by constructing terraced fish ponds for fingerling culture on a comparatively large scale is an innovative feature in the development of fisheries on the Sha Hezi Reservoir.

4.1 Water Quality

One of the main problems encountered in developing the fingerling rearing procedure for Sha Hezi Reservoir was maintaining a high DO content in the terraced ponds. The measures adopted were the reduction of the stratification range of the DO, temperature and pH through gradually increasing the water body and draining water from the bottom of the ponds, so as to increase the utilizable space for fingerling culture.

The exchange of water between the ponds and the reservoir speeds up the recycling of nutrients, which is favourable for the growth of fish as well as fish food organisms, boosting both primary and secondary production in both water bodies.

4.2 Feed and Feeding

A feeding method widely used in pond fish culture in China is to sprinkle the paste or powder-like feed all over the pond. However, there are differences between an ordinary pond used for aquaculture and a terraced pond in the upper reaches of a cove

within an impoundment. These differences are of a morphological nature and the physico-chemical character of water. Sprinkling the feed over the terraced ponds results in much of the feed being lost due to the varying size and depth of the ponds, and it is not fully utilized by fry or fingerlings. Feeding at a certain sector within the terraced pond will result in a differential growth of fingerlings, as feed becomes predominantly utilized by the stronger ones. During the initial stage of feeding, fry feed in a passive state and therefore feed is sprinkled all over the pond. When fry reach a length of 3.5 cm, to prevent a loss of feed and the non-uniform growth of fish, there is a need to gradually lure the fish to feed along the shoreline of the terraced pond, which in practice proves feasible and appropriate. However, the utilization of bean dregs and wheat bran for grass carp and common carp, and the growth rate in ponds with a higher stocking rate of these species was still rather low. For terraced ponds, with a higher stocking density and completely relying on the scattering of paste feed during the late rearing stages, this feeding method is considered inappropriate. It was therefore recommended to use pelleted feed as this would result in a reduced loss of feed.

4.3 Optimal Stocking Density and Stocking Ratio

In the past, the stocking density adopted by the Sha Hezi Reservoir was rather high, 225 000 to 375 000 fry per ha. This was then changed to the following stocking ratio: silver carp 60 to 65 percent, big head 15 to 25 percent, grass carp 10 to 15 percent, and common carp 5 percent. This resulted in a rather low yield per unit and the average size of fingerlings attained at the end of the growth season was only 8.9 cm in length. In 1984, the stocking density was adjusted to 150 000-180 000 per ha and the stocking ratio to 55 percent of silver carp, 10 percent of big head, 15 percent of grass carp, and 20 percent of common carp. The new ratio greatly enhanced the yield per unit and resulted in faster growth. Further adjustments may give even better results. However, under the present conditions in deep ponds, grass carp and common carp should not exceed 30 percent of the total fish stocked.

4.4 Application of Fertilizers

Fertilization is a traditional method implemented in China for the pond rearing of Chinese carp fry. In the past, the Sha Hezi Reservoir also adopted this traditional procedure in fingerling culture by applying organic fertilizers, heaped "Datsao"[1]/ and soaking wild grass. It was observed in practice, however, that organic fertilizers had a slow action, increased the turbidity and made a heavy demand on the dissolved oxygen content. For the past two years, urea has been used instead of organic fertilizers, so as to have better control over the quality of the

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1/ Datsao is a mixed compost consisting of fresh grass and cattle (sheep or pig) feces combined with quicklime, covered with clay to ferment, and applied in ponds after full fermentation.

water. For the reasons stated below, it was considered that terraced ponds should have a transparency of 30 to 46 cm which is higher than in ponds situated in flatlands. This would increase the compensation depth and decrease the volume of poorly oxygenated hypolimnion, giving more water volume to be used by the fingerlings. The use of chemical fertilizers also gave quicker results.

4.5 Management of Over-wintering Fingerlings

The over-wintering period for fingerlings at the Sha Hezi Reservoir is five months (end of November to end of April), with the thickness of ice on the reservoir reaching 70 to 90 cm. To winter fingerlings for distribution during the spring, 75 to 100 t of fingerlings are stocked in 3 to 5 terraced ponds at a density of about 0.25 to 0.55 kg of fingerlings per m^3.

The density of phytoplankton is first determined prior to the freezing of the ponds. When its density falls below 30 mg/l and the DO decreases to between 5 and 6 mg/l after the freezing of the ponds, holes are bored in the ice and chemical fertilizers, with a ratio of 8:2 (nitrogen:phosphate), are put into 1 kg bags which are strung 1 m below the surface. For each hectare of water area, about 30 kg of fertilizer is used. When the phytoplankton density is high, trichlorform, in concentrations of 1.0 to 1.5 ppm, is used to kill the phytoplankton.

5. SUMMARY AND RECOMMENDATIONS

The experience in the culturing of fingerlings in terraced ponds in the Sha Hezi Reservoir can be summarized as follows:

(i) High yielding terraced ponds have a DO content ranging from 6.0 to 8.5 mg/l, a weak alkalinity (pH 7.5 to 8.0), a small variation in temperature and a significant variation in transparency between morning and evening (5 to 10 cm) from June to September.

(ii) There were small differences in the nutrient content of the high and low yielding terraced ponds.

(iii) The composition and quality of phytoplankton in the high and low yielding terraced ponds were similar. The major group of phytoplankton was Cryptophyceae (80 percent). This is different to flatland ponds where blue-green algae dominate and Cryptophyceae account for only 15 percent. In the reservoir water body, 50 percent of the phytoplankton were Cryptophyceae and the phytoplankton biomass was only one-half to one-third of that in the terraced ponds.

(iv) When applying the usual feeds, e.g. paste, and draining water to maintain high water quality in the terraced ponds, the nutrients and the plankton are not the limiting factors in determining the yield of fingerlings.

(v) The major reasons for low yield in some terraced ponds are: shallowness and small volume of water; low compensation depth; poor vegetation covering of the catchment; short shoreline, flat bottom of pond or steep slopes.

(vi) The growth of fingerlings in terraced ponds is most intensive in July and August. After the middle of August, the growth of fingerlings slows down considerably. With sufficient feed and change of water the culture period of the fingerlings could be extended until September.

(vii) The limiting factor for the expansion of fingerlings in terraced ponds is the DO and pH which concentrations are only favourable within the top 3 to 4 m depth. In terraced ponds that exceed 7 m in depth, there is usually less than 5.0 mg/l of dissolved oxygen below 4 m. In ponds of 5 m depth, only the top layer of about 2.5 m can be used by the fingerlings. The filling and draining of terraced ponds improves the conditions by taking more oxygen down to the bottom, hence making the whole water volume available for the fingerlings.

The shortage of fingerlings for stocking reservoirs and the great need for fingerling culture facilities in the immediate vicinity of reservoirs has been felt in many regions of China, especially in the remote ones. This continues to be one of the major constraints in increasing the fish yield from reservoirs. The utilization of terraced ponds for fingerling culture with the purpose of their subsequent use to stock such reservoirs, is shown to be feasible and economically advantageous, as demonstrated with the Sha Hezi Reservoir. The following needs have been identified:

(i) Identification of better feeds for large-size fingerlings of especially grass carp and common carp, shown in terraced ponds;

(ii) Increase in the technical manpower, and the need for advanced technical training for the existing staff;

(iii) Baseline studies of the physico-chemical and biological characteristics of the main reservoir water. There is also a need for more precise data collection on the yield in the reservoir. To evaluate the impact of fingerling stocking on the total reservoir fish yield.

Table 1

Basic characteristics of terraced ponds above the Sha Hezi Reservoir

Pond number	Area (ha)	Maximum depth (m)	Mean depth (m)	Volume (m^3)	Length of shoreline (m)	Remarks
1	2.4	6.0	3.0	72 000	768	
2	3.2	7.0	4.0	128 000	1 275	
3	3.0	8.2	4.5	135 000	1 758	
4	2.26	6.8	3.5	79 300	1 278	
5	0.86	6.0	3.0	26 000	412	
6	0.93	4.0	2.5	23 300	735	Brood fish pond
7	2.0	7.0	3.5	70 000	1 129	
8	0.3	3.0	2.0	6 000	225	
9	1.06	4.0	2.5	26 600	475	
10	0.36	2.0	1.5	5 500	258	
11	0.33	5.8	3.0	10 000	321	
12	3.67	4.0	2.5	91 700	970	
13	11.30	8.5	4.0	453 500	2 190	
Total	31.67			1 126 900		

Table 2

Physico-chemical characteristics of the Sha Hezi Reservoir and three of the terraced ponds

	Reservoir	Ponds		
		No. 2	No. 5	No. 9
1. pH	7.8	7.4	7.6	7.5
2. Dissolved oxygen (mg/l)	10.5	8.1	7.9	7.5
3. Transparency (cm)	19.0	29.2	41.0	45.1
4. Total alkalinity (mg/l)	0.87	1.22	0.91	1.22
5. Nitrate (mg/l)	0.18	0.31	0.70	0.51
6. Nitrite (mg/l)	0.02	0.05	0.10	0.04
7. Total nitrogen (mg/l)	1.34	3.05	3.28	3.82
8. Phosphate (mg/l)	0.99	0.91	0.71	0.76
9. Orthophosphate (mg/l)	0.41	0.47	0.25	0.35
10. Iron (mg/l)	0.27	0.43	0.23	0.62
11. Silicate (mg/l)	11.73	18.78	12.47	18.55